Dielectric Strength Notes
Note 1

Nov. 1965

Comparison of Breakdown Voltages for Various Liquids Under One Set of Conditions

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First Printed as SSWA/JCM/1165/8

The conditions used in these experiments were parallel plates of the order of 16 square inches in area which had carefully radiused edges so that there was no field enhancement at them. The gaps used varied between 6 mm and 12 mm usually, and the effective times of charging between .15 and .3 microseconds. The relation to which the breakdown voltages are fitted is $F^{3/2}t$ where F is in MV/cm and t is the full width in time of the pulse at 63% of the peak voltage reached. In general the results gave a reasonably constant value of this function (k) and in the case of alcohol the standard deviation of the results was very good, being about 12% for a single result. However, for ethylene glycol there was evidence that the fit was not so good and for water the relationship is significantly different. A value of k is quoted for water but this is estimated for these particular conditions; for high voltages and bigger gaps water gets progressively better.

The figure of merit you employ will vary with the application you have in mind. What I have selected to tabulate is $\varepsilon k^{4/3}$ which is proportional to the energy per cc at the breakdown point for a given constant charging time.

Some work was also done with cross cylinders and these gave values in reasonable agreement with the parallel plate values. The plates used became slightly dented as the experiments proceeded but care was taken that there was no tendency to break consistently at one point or at the edges. In the case of glycerine, the liquid had to be stirred after each breakdown and it was very pretty to see the discharge trees at points other than that which got across first. These patterns were thin white threads frozen in place after the voltage had been removed by the breakdown and were very heavily branched. There were usually a few (like 3 or 4) fairly big ones in any one shot, all coming from the positive plate. There was nothing at all growing from the negative plate. All the liquids were stirred reasonably well but glycerine required a lot of stirring. The plates in these tests were vertical, so bubbles could escape upwards.

Not given in this list is data obtained with smooth ball bearings in a small volume test. This data was in line with these tests but in general gave bigger values for k , perhaps implying an area term. One substance that gave quite remarkable results with the small area test was acetic acid. However, I could not bring myself to test it in the larger area test, in case it continued to be good. (Imagine several tons of the stuff). Likewise several other materials were checked in the ball bearing test but excluded in the tests reported here, which were of materials it was possible to conceive of working with.

The conductivity of the alcohols was a bit embarrassing, but with care the resistance of the cell was kept in the kilohm region. Ian also did some work on de-ionizing them with resin columns, which seemed to work quite O.K.

TABLE

Values of $F^{3/2} \; t_{eff} = k$

Area of plates : 16 square inches

The dielectric constant taken from standard tables not measured.

Material	k	ε	$\varepsilon k^{4/3}$
Ethyl Alcohol	.057	24)	
" " + 1% water	.059	24.6)	0.56
" " + 10% water	.052	29.6)	
Methyl Alcohol	.052	33	0.65
Ethylene Glycol	.03	38	0.34
Glycerine	.010	44	0.10
Castor Oil	.11	4.7	0.25
Transformer Oil	.08	2.4	0.09
Water	.03	80	0.72

Note: Values of k are good to perhaps 10 to 15%.